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(54) Hearing aids

(57) A hearing aid has two parallel channels 1 and 2 with different amplifying characteristics. Channel 1 has a characteristic which increases with frequency over the mid range of frequencies while channel 2 has a characteristic which provides relatively constant amplification over all frequencies. Channels 1 and 2 include respective gates 5 and 6 which are controlled by a decision circuit 7 which distinguishes between voiced and unvoiced speech components so that channel 1 passes voiced components and channel 2 passes unvoiced components. The aid can be used with a higher gain setting than conventional aids without causing discomfort.

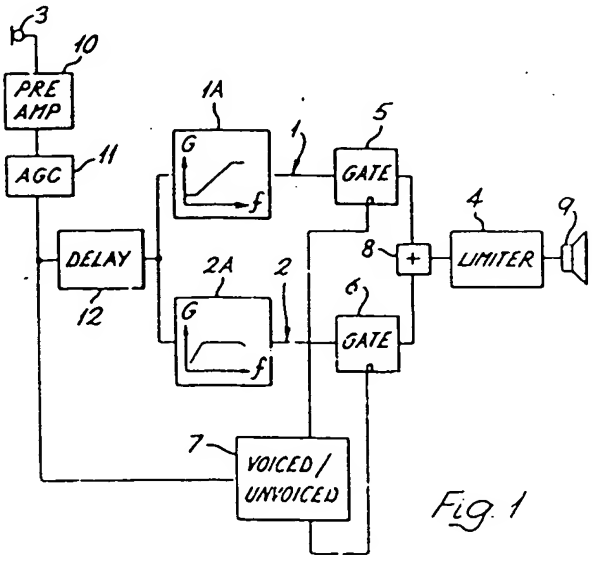

Fig. 1

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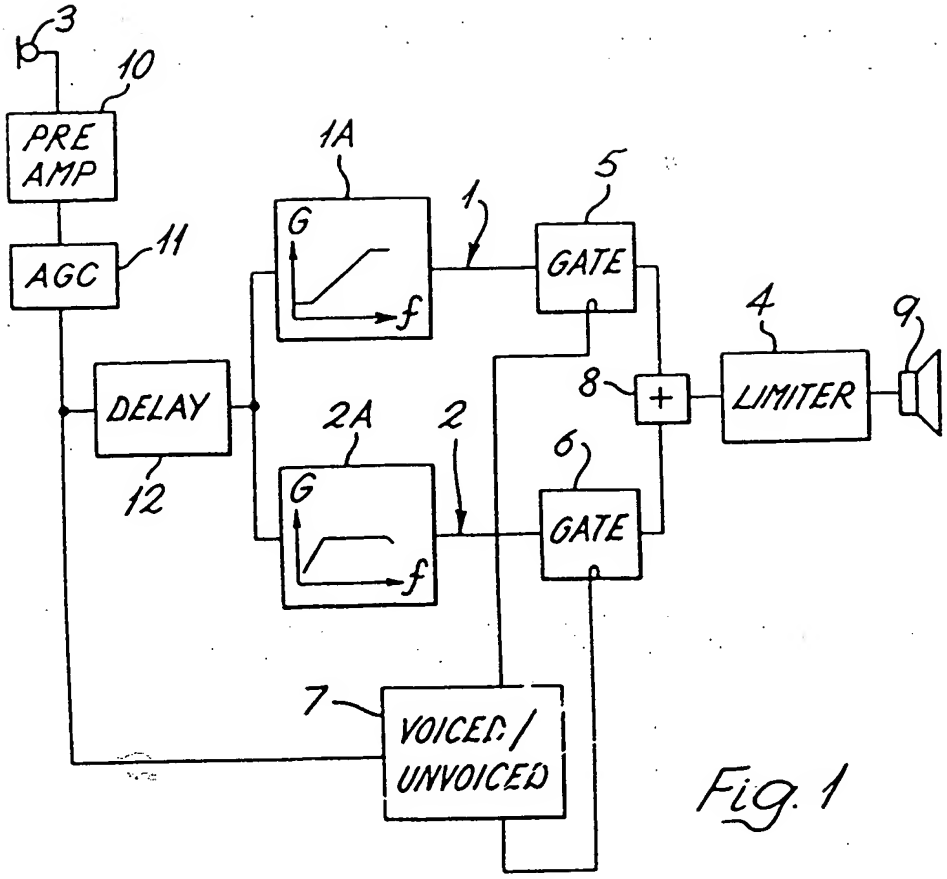
3
10
PRE AMP
11
AGC
DELAY
12
1A
G
f
1
5
GATE
2A
2
G
f
6
GATE
8
+
4
LIMITER
9
7
VOICED / UNVOICED

Fig. 1

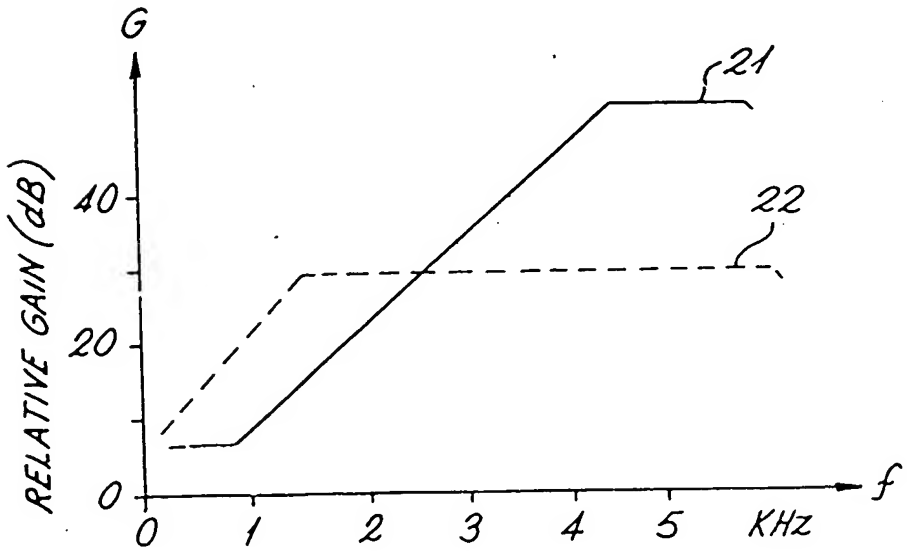
G
21
22
40
20
0
RELATIVE GAIN (dB)
f
0
1
2
3
4
5
KHz

Fig. 2

SPECIFICATION

Hearing aids

This invention relates to hearing aids.

Simple forms of hearing aid which provide for overall amplification of the entire spectrum of speech signals are not always satisfactory for more severe impairments of hearing. This is due to the threshold of loudness discomfort in a user of a hearing aid being near the same level in a person not requiring an aid despite loss of hearing. The user will therefore reduce the gain of an amplifying aid to that level where no frequency components intrude significantly into the region of discomfort. Where the frequency response has not been optimised components in the mid and high frequency range will therefore not be presented at their individual optimal gain levels and will be masked by more intense sounds of lower frequency.

As a simple general solution amplifiers for use in hearing aids may have a continuously rising frequency response. A figure of 12 dB per octave above 750 Hz has been recommended and is preferred in some cases. However, at high gain settings such as response will put certain speech sounds at conversational levels into the discomfort region, thus cause a user to reduce the overall gain setting that would be utilised in practice and reducing the efficacy of the hearing aid.

Speech signals may be divided into voiced and unvoiced components. Most of the sounds in speech are voiced, the ratio of voiced to unvoiced portions when averaged over the long-term being approximately 80% to 20%. Consequently, unvoiced sounds do not represent a high proportion of the long-term energy in individual frequency bands, except at quite high frequencies. However, unvoiced signals do have short-term peak levels in the mid to high frequency range equal to or greater than those of voiced sounds in that range. If an amplifier with a rising frequency response is provided, it will be certain of the high frequency unvoiced components that cause a listener the most discomfort and which will, therefore, result in the turning-down of the volume control. This lowers the usable gain of the middle and highr frequency components of the voiced portions of speech.

It is an object of the invention to provide a hearing aid with an amplifying characteristic in which amplification of the different components of speech signals are separately optimised and held below an uncomfortable level of loudness while minimising the disadvantage associated with the use of non-linear circuits.

According to the invention, a hearing aid comprises microphone means for converting sound waves into electrical signals, a plurality of parallel amplifying channels having different amplifying characteristics, means for distinguishing between components of the electrical signals in accordance with the intensity of their high frequency content, means for enabling the respective components to be passed through different ones of the said channels, and means for re-converting the combined signals to sound waves.

In carrying out the invention it may be convenient to provide two amplifying channels. The means for distinguishing between components of the electrical signals preferably operates to distinguish between voiced and unvoiced components since it is the unvoiced components which have short-term high-intensity peaks at the high-frequency end of the speech spectrum.

Preferably, the amplifying channel used for passing the voiced components has an amplifying characteristic which increases with frequency over the mid-range of speech frequencies, and the amplifying channel for passing the unvoiced components has a characteristic which is relatively constant over the mid and high-range. Each component of speech will thus be separately amplified in a manner which will tend to equalise or flatten the long-term spectrum of that component.

Gates may be included in each of the said channels, which are controlled by the said distinguishing means.

In order that the invention may be more fully understood, reference will now be made to the accompanying drawings in which:–

Figure 1 is an overall block diagram of a hearing aid embodying the invention, and

Figure 2 is a gain/frequency curve for the circuit of Figure 1.

The hearing aid shown in Figure 1 has a microphone 3 which feeds a pre-amplifier 10. The output of pre-amplifier 10 is applied through an optional automatic gain control circuit 11 to a delay circuit 12 and to a decision circuit 7 which distinguishes between voiced and unvoiced components of speech. The output of delay circuit 12 is applied through two parallel channels 1 and 2 to respective gates 5 and 6. Channel 1 includes an amplifier 1A and channel 2 includes an amplifier 2A. Gates 5 and 6 are controlled by the decision circuit 7 so that either one or other gate is open. The outputs from gates 5 and 6 are summed in a summing circuit 8 and passed through an optional limiter 4 to a suitable earpiece 9.

The overall amplifying characteristic of channel 1 when taken in combination with the characteristic of pre-amplifier 10 is such that it has a characteristic which increases with frequency over the mid-range of speech frequencies. The overall amplifying characteristic of channel 2 when taken in combination with the characteristic of pre-amplifier 10 is such that it provides a relatively constant amplification over all frequencies. In practice it may be convenient to provide the pre-amplifier with a characteristic which rises with frequency, this characteristic being enhanced in amplifier 1A and de-emphasised in amplifier 2A. This arrangement may improve the internal signal-to-noise ratio of the hearing aid.

Typical amplification characteristics for the two channels 1 and 2 are shown in Figure 2. This Figure shows the general form of relative gain G against frequency f required at the outputs of the respective channels 1 and 2 to realise the benefits of channel separation. The gain of channel 1 is shown by the

shown by the dotted-line curve 22. The relative gains shown in Figure 2 embody the generally desirable crossing of the two amplifier characteristics in the mid frequencies, but the precise balance and characteristics of the different amplifier channels may be modified from that shown in the light of experience or to meet the needs of particular patients.

Circuit 7 distinguishes between voiced and unvoiced components of speech and opens gate 5 or 6 to the speech component detected. According to the requirements of particular patients, and according to the degree of complexity of circuit 7 and to its parameter adjustments, the circuit may closely approximate a true-voiced/unvoiced decision mechanism or more simply activate gate 6 only for the subset of sounds having most high-frequency content and commonly spelled "S, Sh, Ch, T". In order to make switching of circuit 7 stable and not subject to flutter with incidental noise, various accessory functions may be incorporated in the circuit, including an averaging period, hysteresis and a bias which may be controlled adaptively by the recent history of switch states. Hence the output from circuit 7 to open and close gates 5 and 6 will be subject to inevitable delay. To ensure that intense signals do not pass through the inappropriate channel delay unit 11 introduces a constant delay to the signal path in the regions of 10ms to parallel the delay in the control path arising from the accessory functions incorporated in circuit 7.

Channel 1 carries voiced components and channel 2 carries unvoiced components. The precise gain frequency characteristic of both amplifiers can be altered to suit the requirements of different users. The desirable effect achieved by the hearing aid illustrated in Figure 1 is that unvoiced components which contain intense short-term signals in the mid and high-frequency range will not have these frequencies amplified preferentially and accordingly, unvoiced components in the combined signal in earpiece 9 will not cause discomfort or hence restrict the overall gain used.

An advantage of the hearing aid described above is that only a limited number of non-linear circuits need be employed and the extent to which speech signals enter non-linear operating ranges is restricted.

In use of the hearing aid it is desirable to encourage the use of higher average gain values than are typically tolerated with a simple amplifier. To this end the limiter 4 may be included for greater protection against intense sounds. This serves to encourage variation by the audiologist or by the patient of the parameter settings of the two amplifier channels to find the best setting since mis-setting or equipment malfunction is guarded against. The optional AGC circuit 11 may be included to restrict the electrical dynamic range over which the essential electrical functions of the aid need be carried out. It may be additionally useful to apply degrees of control in suiting the aid to more impaired patients.

CLAIMS

1. A hearing aid comprising microphone means for converting sound waves into electrical signals, a plurality of parallel amplifying channels having different amplifying characteristics, means for distinguishing between components of the electrical signals in accordance with the intensity of their high frequency content, means for enabling the respective components to be passed through different ones of the said channels, means for combining the outputs of the channels and means for re-converting the combined signals to sound waves.

2. The hearing aid as claimed in Claim 1 in which two amplifying channels are provided.

3. The hearing aid as claimed in Claim 1 or Claim 2 in which the means for distinguishing between components of the electrical signals operates to distinguish between voiced and unvoiced components.

4. The hearing aid as clamed in Claim 3 in which the amplifying channel used for passing the voiced components has an amplifying characteristic which increases with frequency over the mid range of speech frequencies.

5. The hearing aid as claimed in Claim 3 or Claim 4 in which the amplifying channel for passing the unvoiced components has a characteristic which is relatively constant over the mid and high range of speech frequencies.

6. The hearing aid as claimed in any one of the preceding claims in which gates are included in each of the said channels, which gates are controlled by the said distinguishing means.

7. A hearing aid as substantially described with reference to the accompanying drawings.

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